N88-17618

RESPONSE OF WIND SHEAR WARNING SYSTEMS TO TURBULENCE WITH IMPLICATION OF NUISANCE ALERTS

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TURBULENCE RESPONSE OF WIND SHEAR WARNING SYSTEMS

STUDY OBJECTIVE

PREDICT THE INHERENT TURBULENCE RESPONSE CHARACTERISTICS OF CANDIDATE WIND SHEAR WARNING SYSTEM CONCEPTS AND ASSESS POTENTIAL FOR NUISANCE ALERTS

FACTORS CONSIDERED

- O DEVELOPMENT OF ANALYSIS TOOLS
- O SYSTEM CONCEPT BASED ON F-FACTOR HAZARD INDEX
- O TURBULENCE INDUCED THRESHOLD EXCEEDANCE PROBABILITY
- O HAZARD THRESHOLD VS. SYSTEM LATENCY TRADE STUDY

WIND SHEAR "HIT"

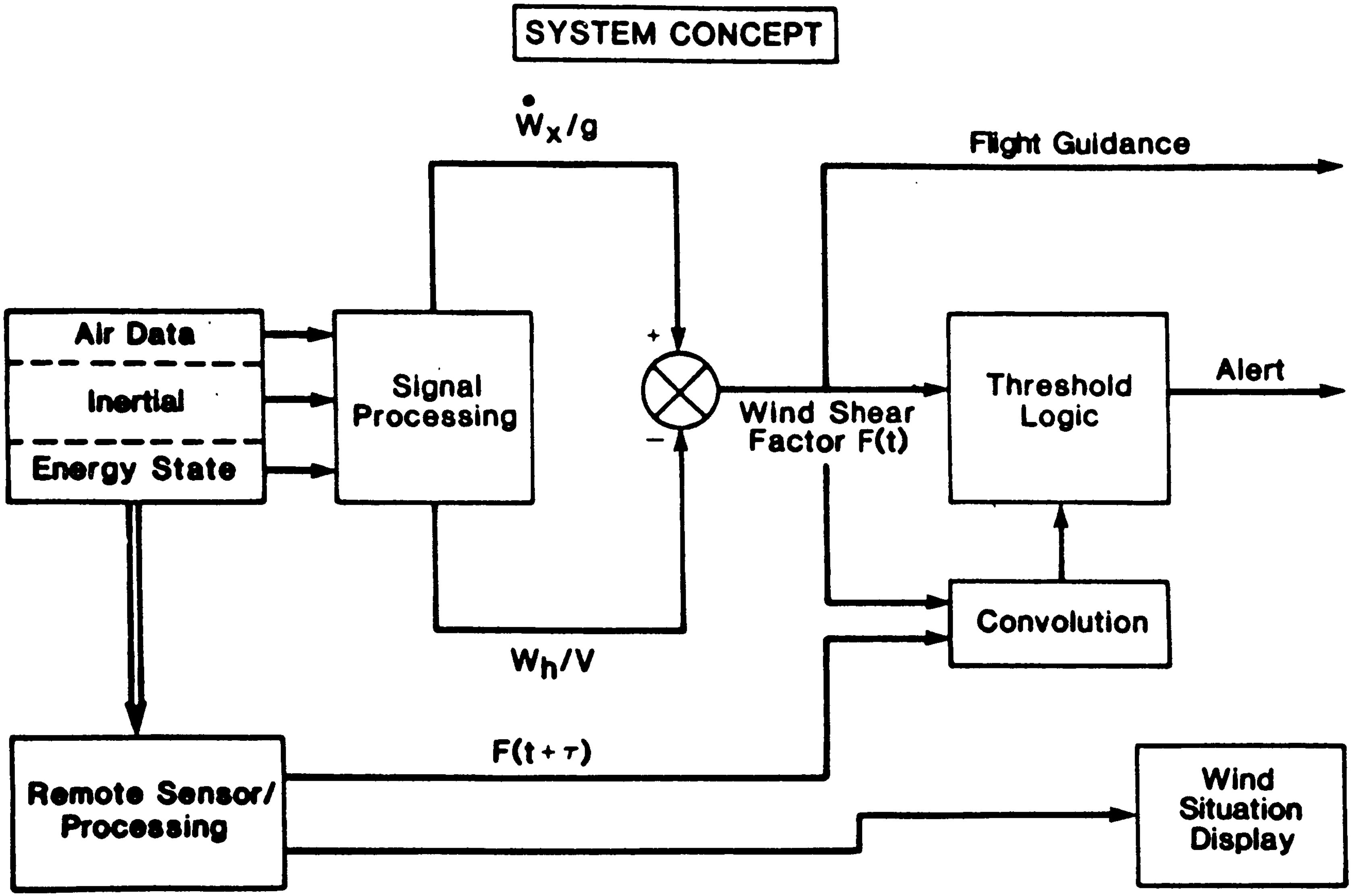
- O HAZARD INDEX: $F = \frac{\dot{W}_x}{g} - \frac{W_h}{V}$

- Q ALERT AND WARNING THRESHOLD DETERMINED BY MAX. PERMISSIBLE F IN RELATION TO AVAILABLE AIRCRAFT PERFORMANCE CAPABILITY

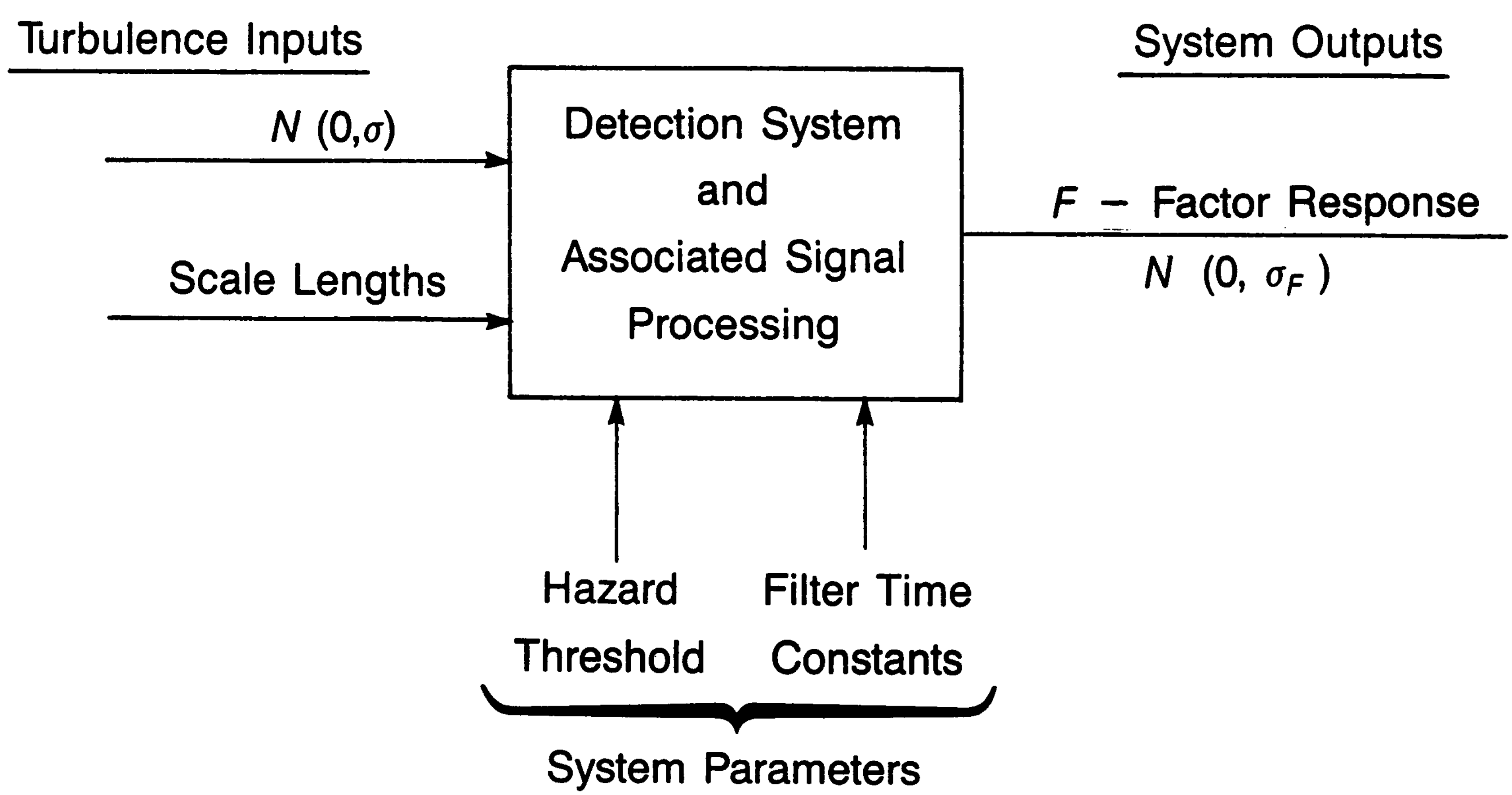
- O F IS A SENSED QUANTITY

- O HAZARD INDEX APPLICABLE TO BOTH INSITU–SENSED INFORMATION AND REMOTE–SENSED WIND SHEAR

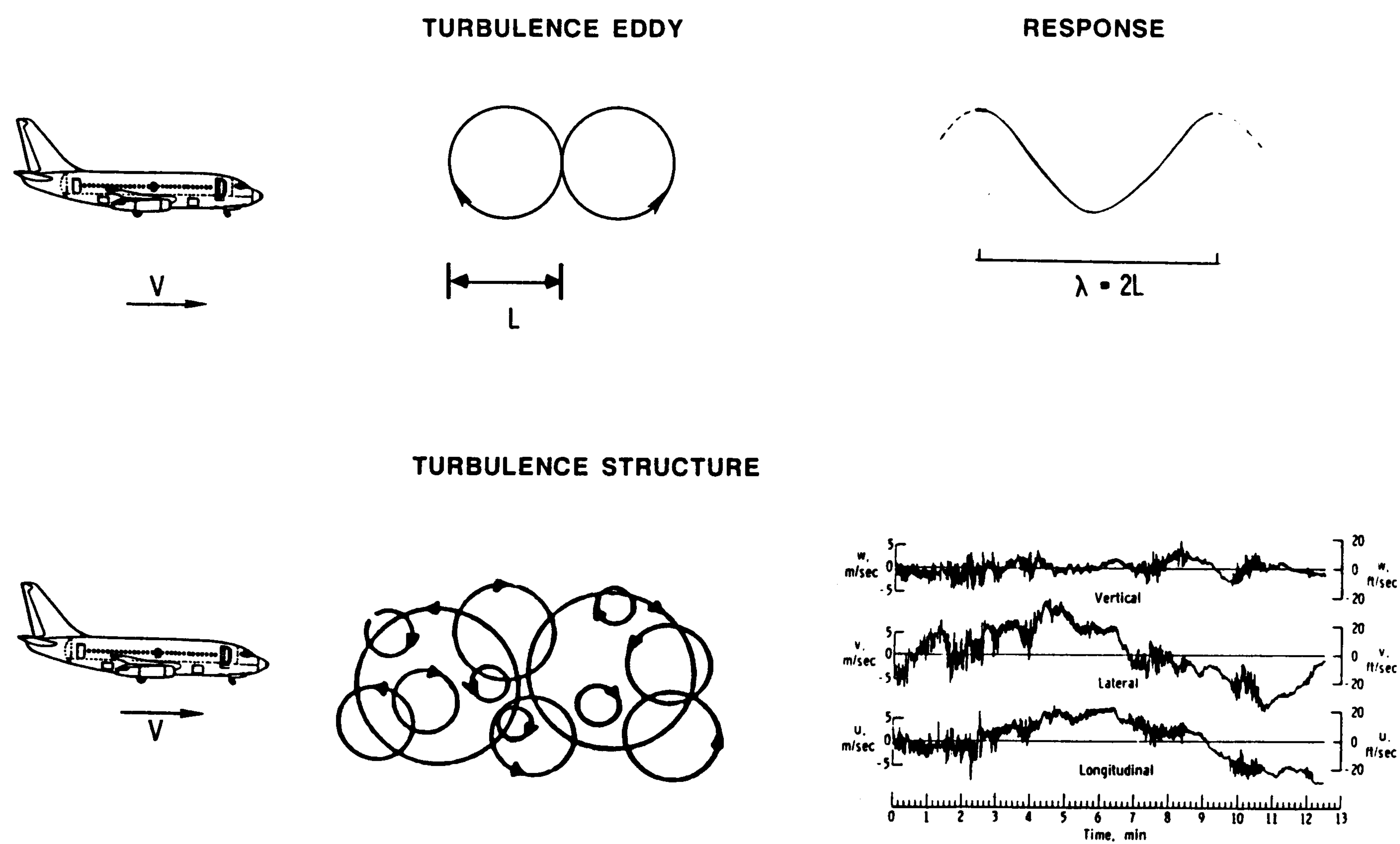
FUSION OF PRESENT POSITION AND PREDICTIVE INFORMATION



TECHNICAL APPROACH



PHYSICAL MODEL



MATHEMATICAL MODEL

- $F = \dot{w}_{x/g} - w_{h/v}$
- $w_x \, ; \, w_h$ Random Uncorrelated Turbulence
- $\sigma_F^2 = \sigma_{\dot{w}x/g}^2 + \sigma_{wh/v}^2 \qquad \sigma^2 = E\,[\,(x - \bar{x})^2\,],\ \bar{X} = E\,[\,x\,] = 0$
- $\sigma_F^2 = \int_{-\infty}^{\infty} (\phi_{\dot{w}x/g} + \phi_{wh/v})\, d\,\Omega$
- Dryden Turbulence Model Selected
- Rate Estimator

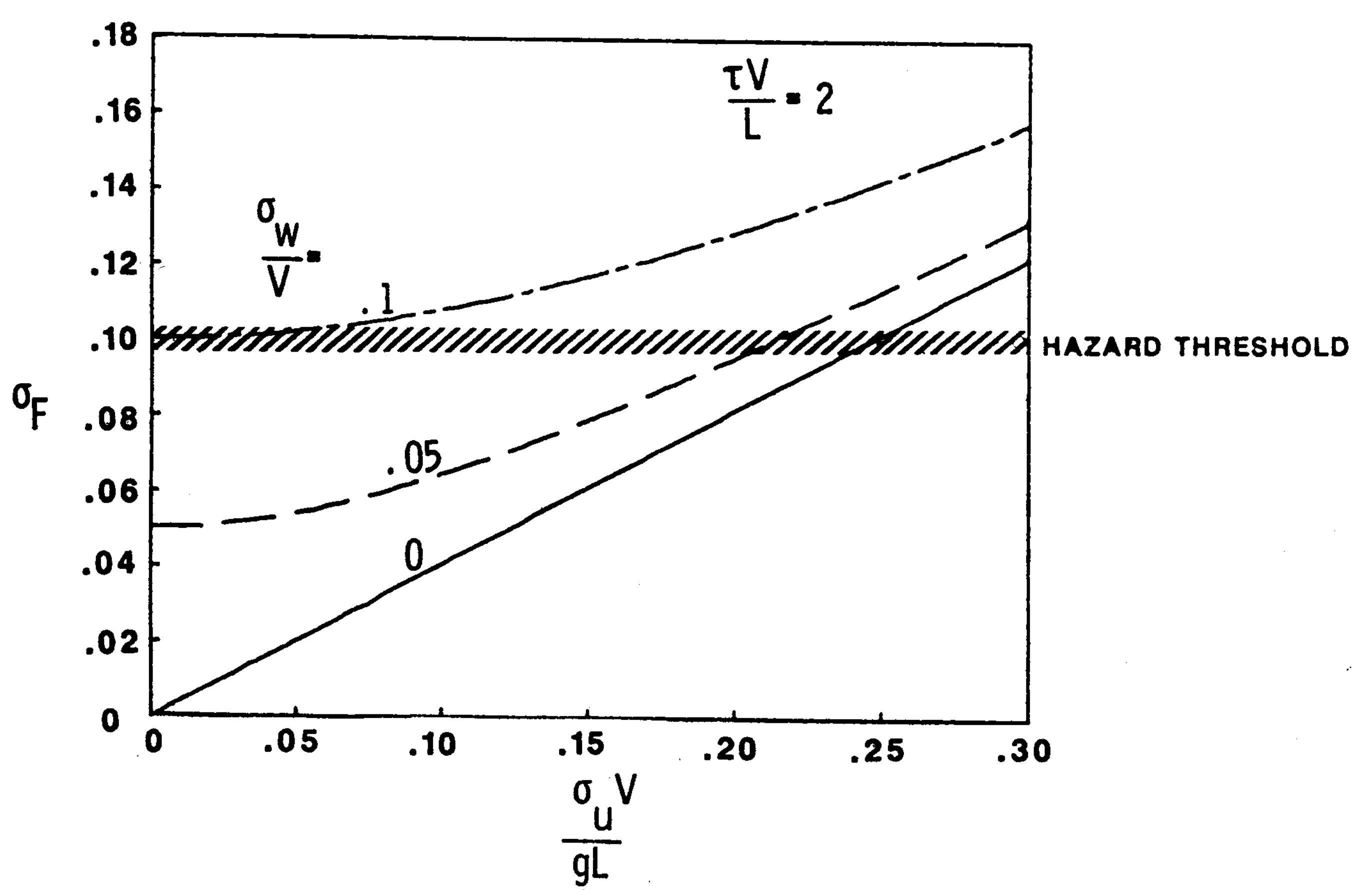
F–FACTOR ROOT MEAN SQUARE TURBULENCE RESPONSE

$$\sigma_F = \frac{\sigma_W}{V}\left[\frac{V^2}{\mu^2}\left(\frac{\sigma_U}{\sigma_W}\right)^2 + 1\right]^{1/2}$$

$$\mu = g\,\tau\,\sqrt{1 + L / V\tau}$$

$g =$ 32.2 ft/sec^2
$V =$ Airspeed ft/sec
$\tau =$ Rate Estimator Time Constant sec.
$L =$ Longitudinal Turbulence Scale Length ft
$\sigma_U =$ RMS Longitudinal Turbulence Intensity ft/sec
$\sigma_W =$ RMS Vertical Turbulence Intensity ft/sec

STANDARD DEVIATION OF F-FACTOR DUE TO TURBULENCE



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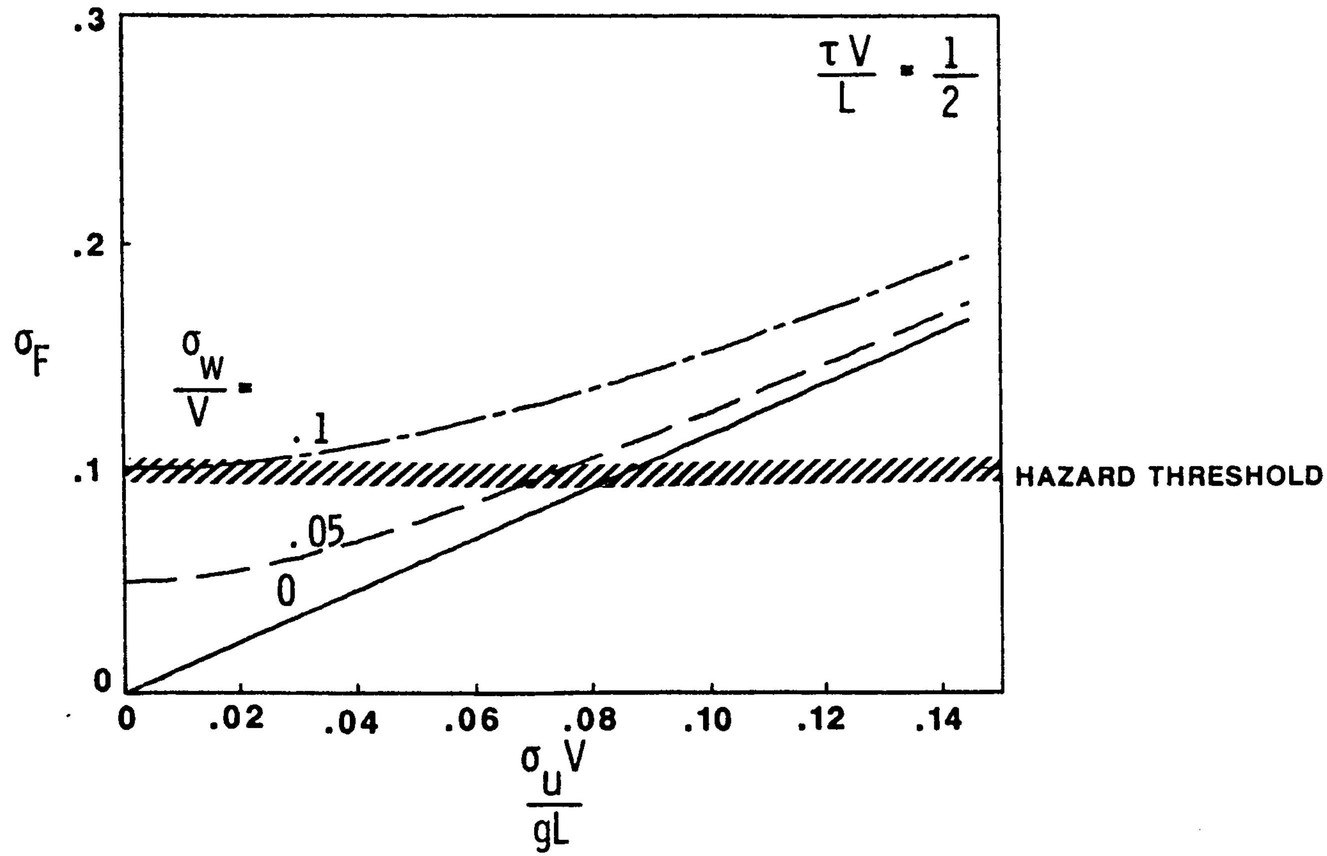

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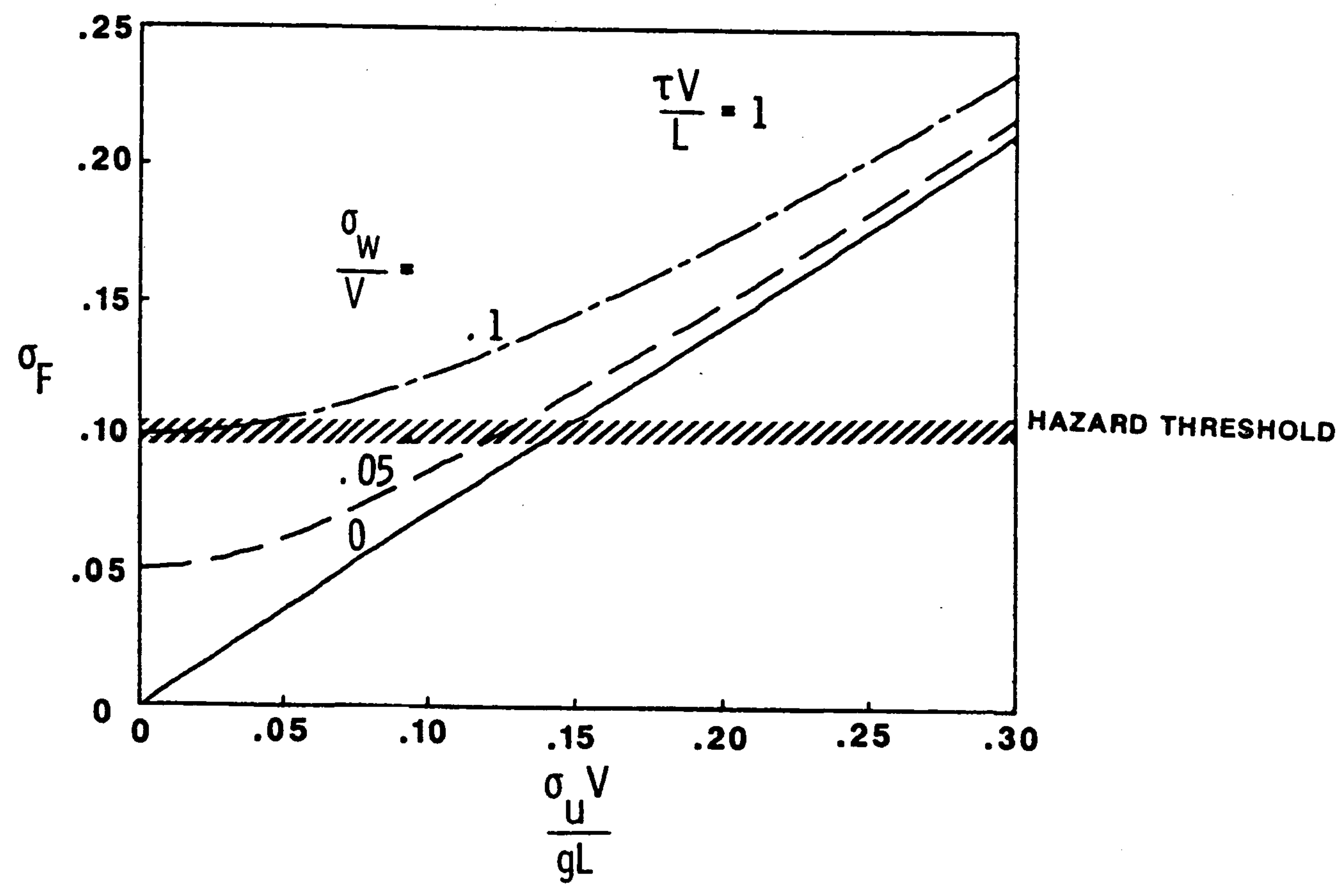
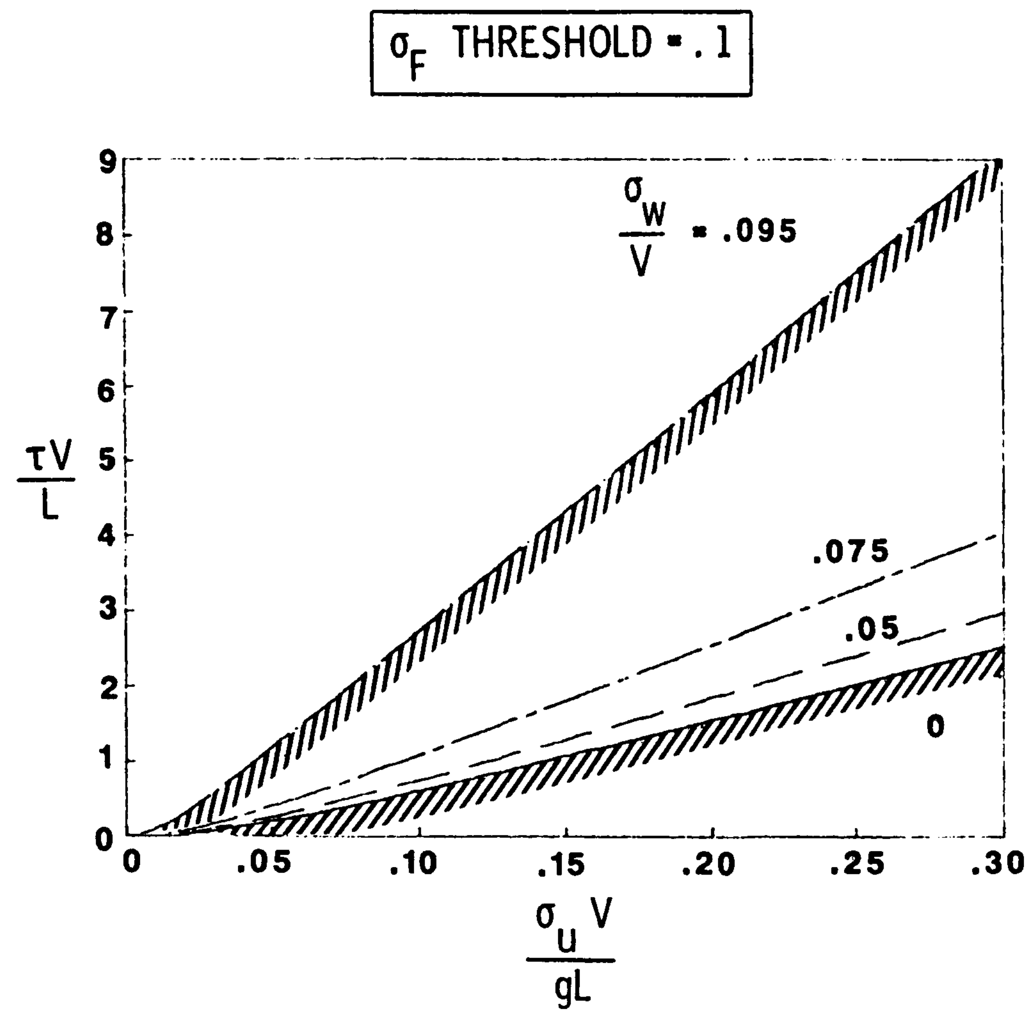
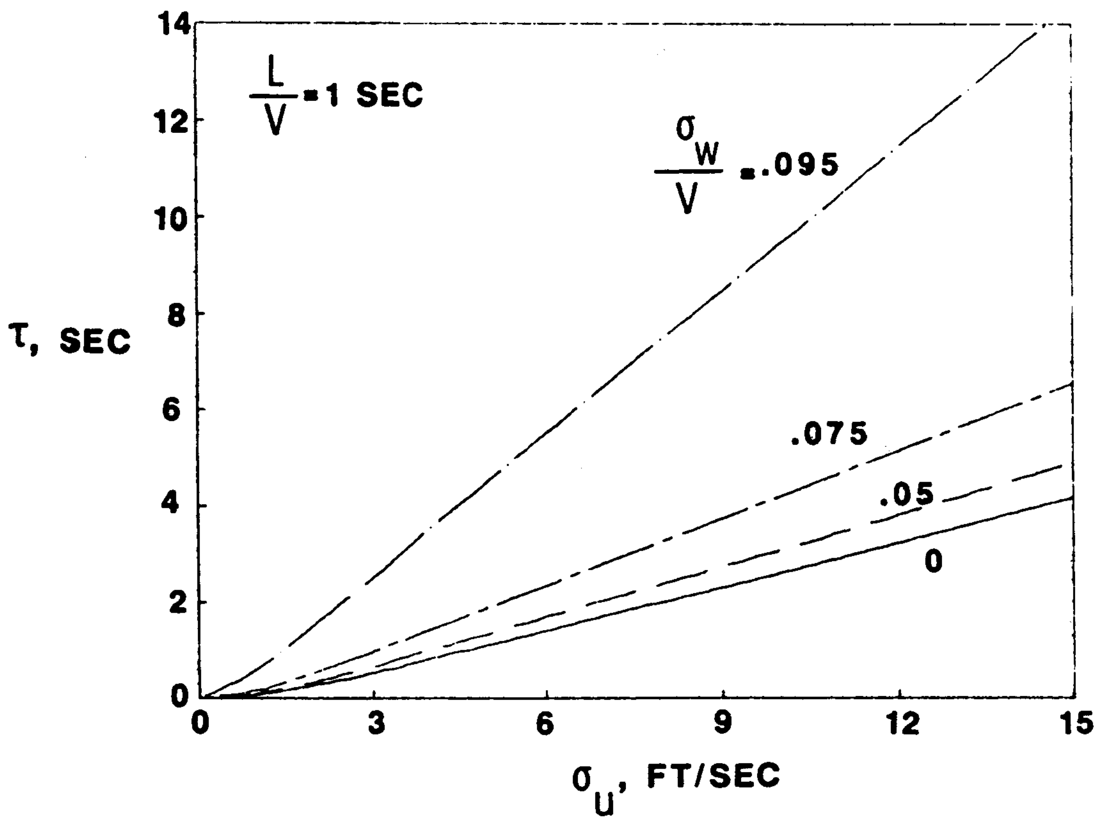


REQUIRED $\frac{\tau V}{L}$ BOUNDARIES TO MAINTAIN THRESHOLD INTEGRITY



TAU REQUIRED TO SATISFY THRESHOLD CRITERIA

UNFILTERED VERTICAL CHANNEL



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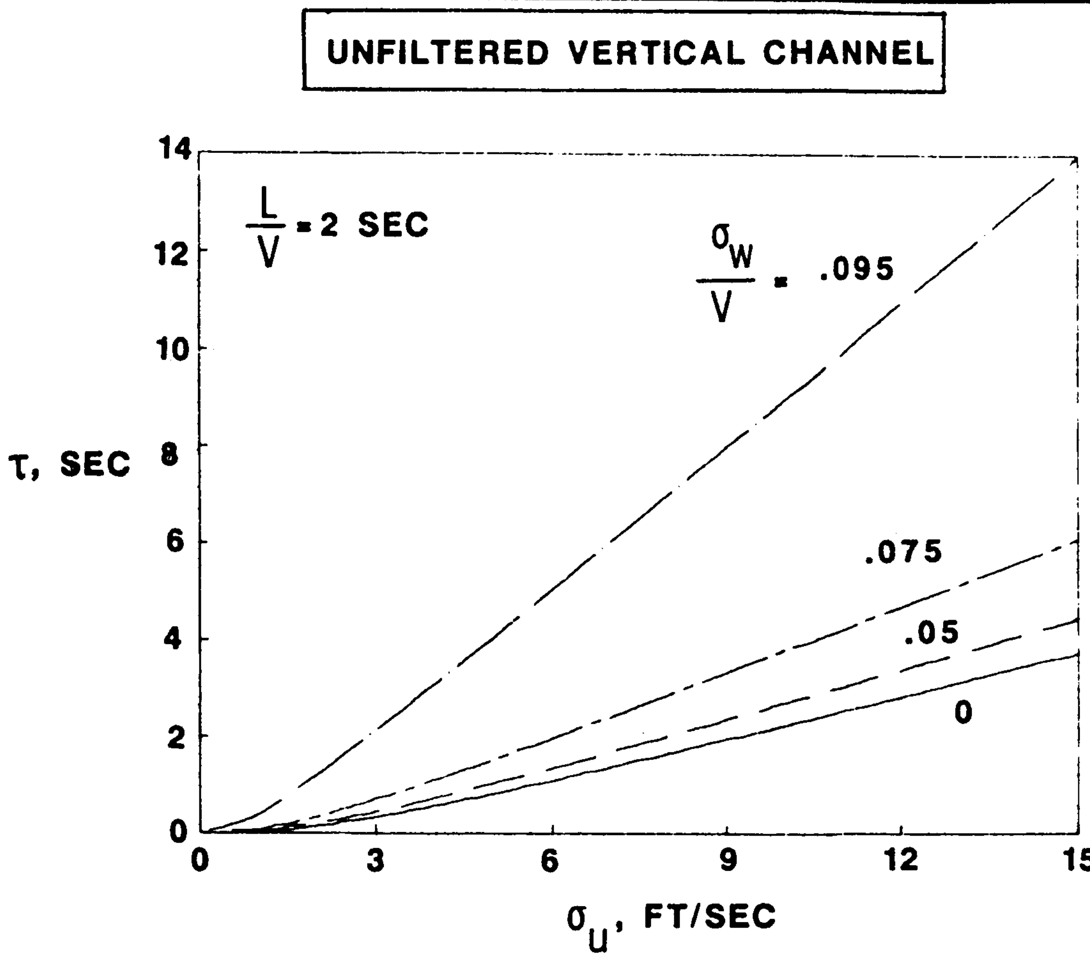

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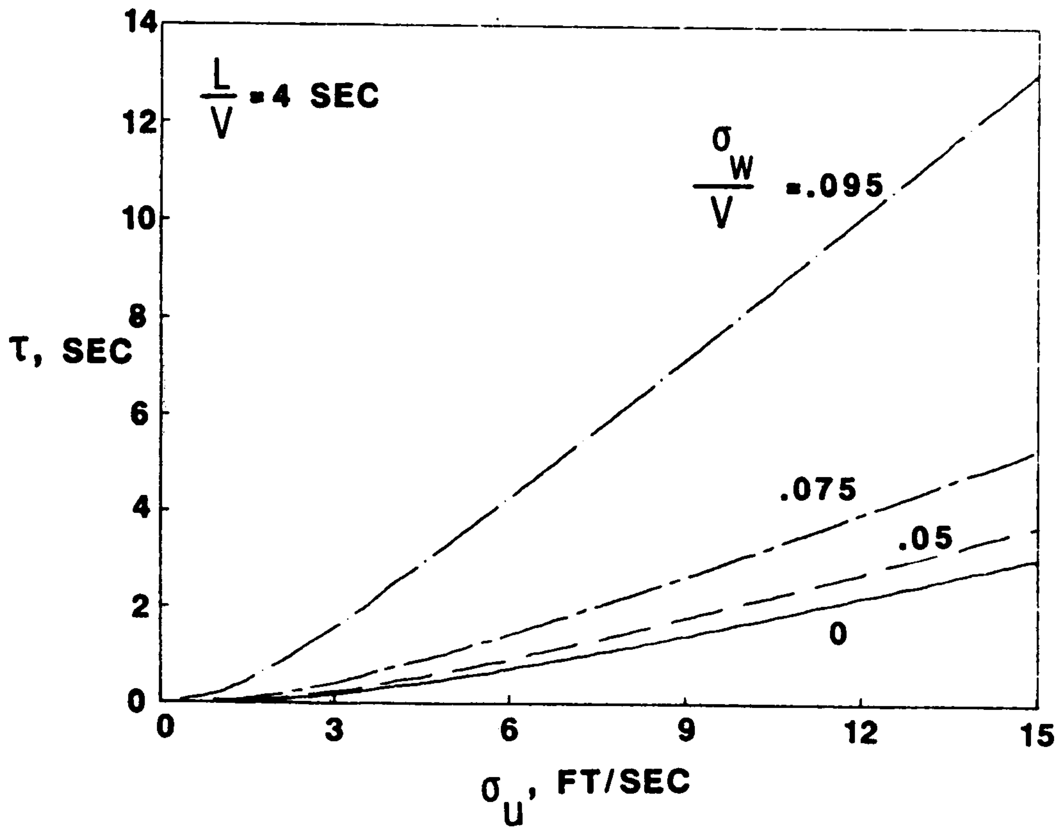


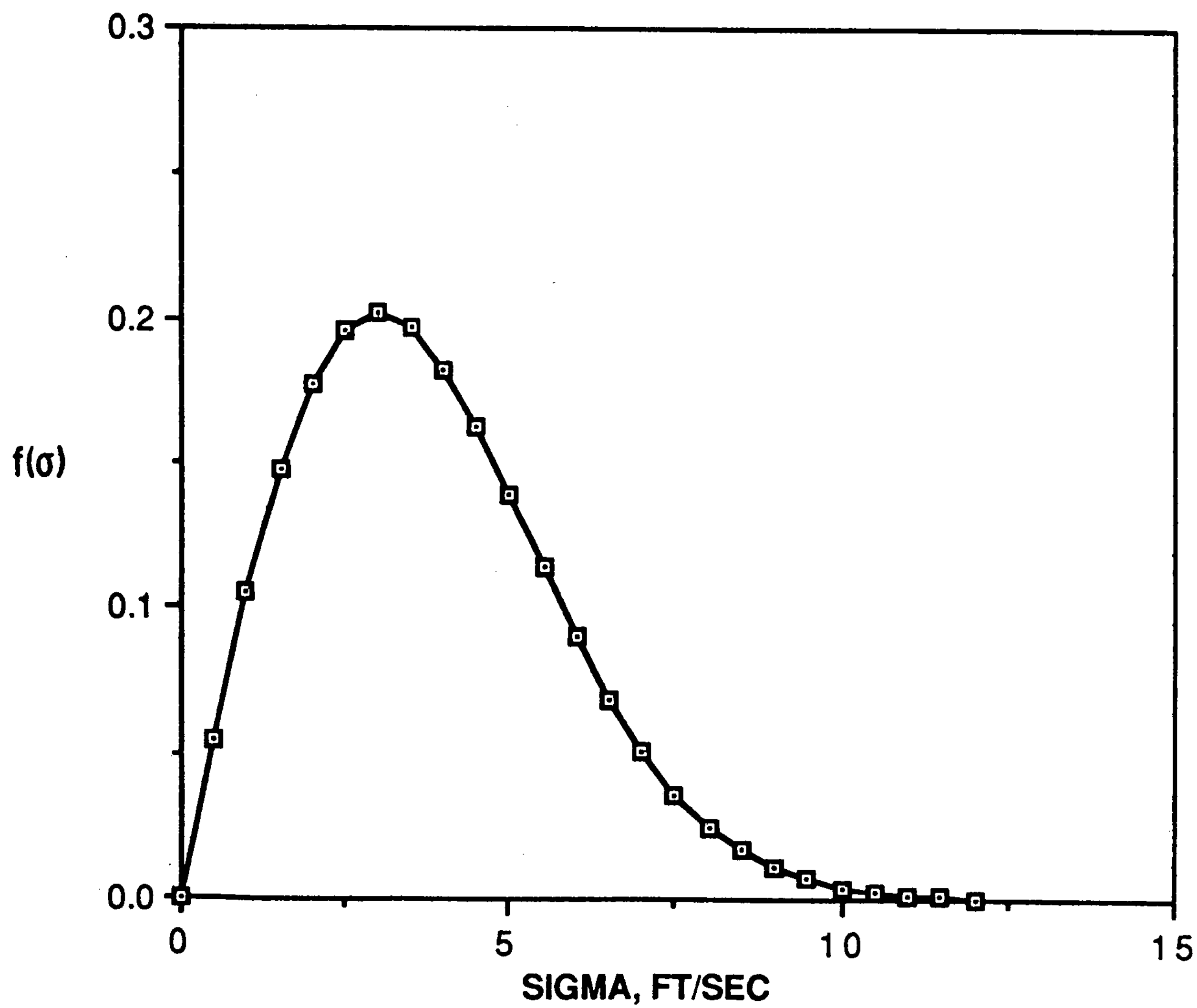
F–FACTOR EXCEEDANCE PROBABILITY ONCE TURBULENCE IS ENCOUNTERED

$$P(F \geq Z) = \int_0^{\infty} P\,(\,F \geq Z\,/\,\sigma_F\,(\,\sigma\,))\,f\,(\sigma)\,d\sigma$$

$$P\,(\,F \geq Z\,) = f\,(\,\tau,\,Z,\,V,\,L\,)$$

$\boxed{\text{Provides Basis for Parametric Trade Studies}}$

RMS GUST VELOCITY PROBABILITY DENSITY (NEUTRAL LAPSE RATE)



TURBULENCE CONDITIONS

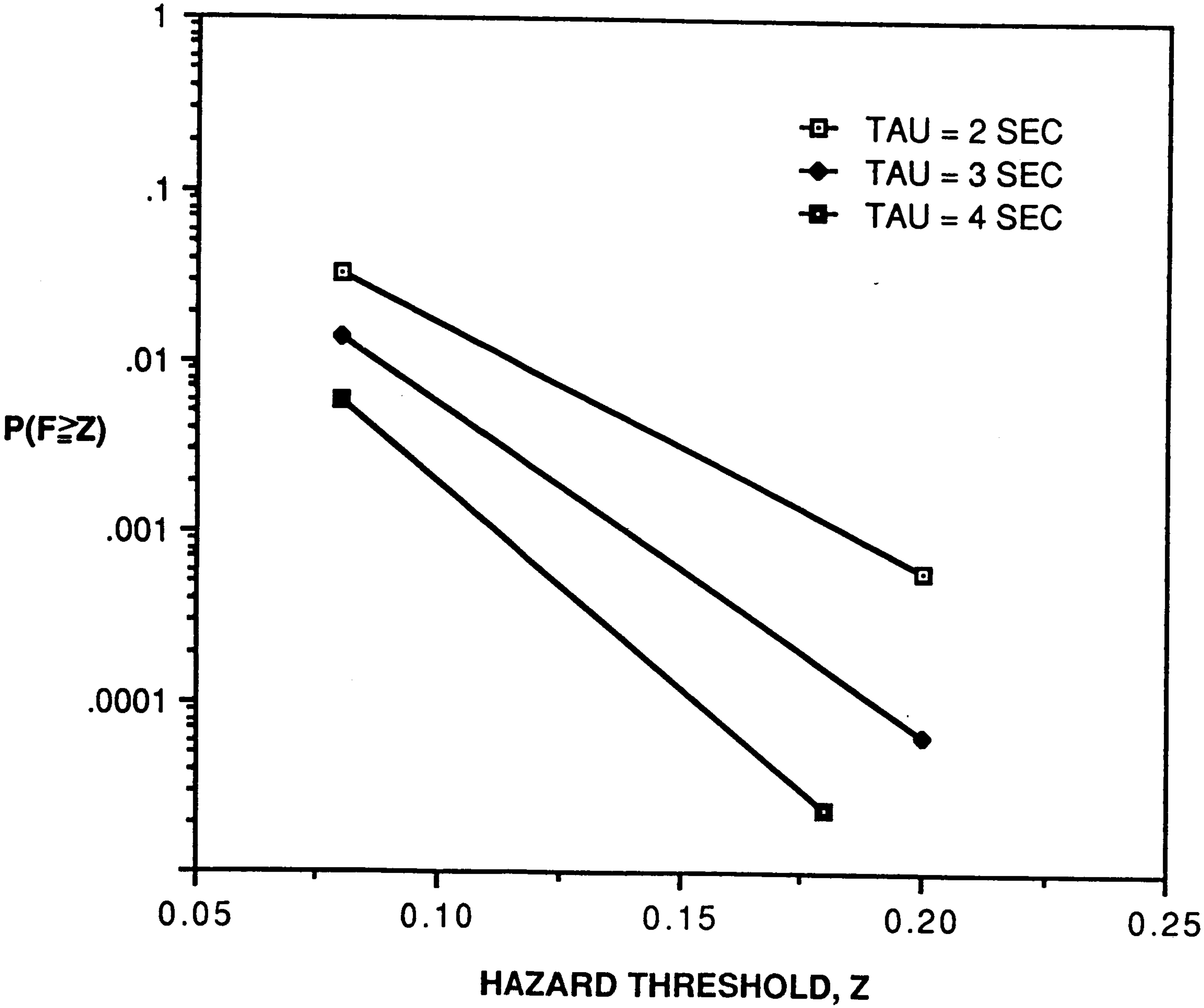
$$\sigma_u = \left(\frac{\sigma_u}{\sigma_w}\right)\sigma_w$$

Application:

$\frac{\sigma_u}{\sigma_w} = 1$ Altitude $\geq$ 1000 ft (Isotropic)

$\frac{\sigma_u}{\sigma_w} = 2$ Altitude $<$ 1000 ft

F EXCEEDANCE PROBABILITY DUE TO TURBULENCE



HAZARD THRESHOLD VS. RATE ESTIMATOR TIME CONSTANT